Research Article

Comparative Evaluation Of Shear Bond Strength Of Biodentine And Theracal Lc Using 6th, 7th & 8th Generation Dentin Bonding Agents Restored With Monochromatic Composite Material: An In-Vitro Study

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Abstract

Background: In minimally invasive dentistry, adhesive restorative materials are widely used both as bulk restoration and for repair of occlusal, cervical and proximal surface of the tooth.
AIM-the aim of this in-vitro study was to assess and compare the shear bond strength of bonding agents from the sixth, seventh, and eighth generations when used in along with pulp capping agents, Biodentine and Theracal LC restored with monochromatic composite.
Materials and methods- 60 premolars extracted tooth were taken for the study. Samples are then divided into two groups namely, Group A (Biodentine group) and Group B (Theracal Lc) respectively. Each group is then further subdivided into subgroup A1 and B1 (6th gen dentin bonding agent), subgroup A2 and B2 (7th gen dentin bonding agent) and subgroup A3 and B3 (8th gen dentin bonding agent). shear bond strength testing was done by universal testing machine; the maximum load was recorded during testing.
Results- It was noted that the mean shear bond strength was highest in the Theracal Lc + 8th gen G-Premio bond (25.147±1.4) followed by Theracal LC + 7th gen 3M universal bond group (22.519±1.80), the Theracal Lc + 6th gen Shofu Fl bond II (20.6±1.957), Biodentine + 8th gen G-Premio bond (12.08±1.46), Biodentine + 7th gen 3M universal bond (10.499±1.564) and least shear bond strength was found in the Biodentine + 6th gen Shofu Fl bond II (9.926 ±1.24).

Keywords: shear bond strength, Theracal LC, Biodentine, composite.

Introduction-

Dental caries is still one of the most common chronic diseases across the globe and is characterized by the destruction and demineralization of tooth structure over time.[1] It is important to restore the deep carious teeth with a suitable dental material with properties similar to that of tooth structure, for effective masticatory functions. Recent developments in dental material sciences have introduced materials with properties close to dentin and enamel.[2] Biodentine can be used as a dentine substitute for coronal restorations, such as indirect pulp capping, and can also be placed safely in direct contact with the pulp.[3] TheraCal LC is a modern, light-cured material that combines resin with calcium silicate, developed to serve as a protective base or liner in both direct and indirect pulp capping.[3] Dental adhesive technology has been advanced rapidly in the recent years, with manufacturers consistently introducing new systems that highlight easier application, improved adhesive formulations, and stronger bonding to tooth structures. Tests measuring microleakage and bond strength are widely used worldwide to verify these claims and assess how effectively different adhesives bond to teeth. Bond strength, which calculates the initial force needed to break the bond divided by the bonded area, is regarded as a dependable indicator of how long dental restorations will last. However, despite many important guidelines proposed, there remains a lack of full standardization in how bond strength tests predict real-world clinical performance of dental adhesives.[4] In light of these advancements in adhesive dentistry, this study aims to compare how well three different generations of bonding agents adhere to Biodentine and TheraCal LC when used under a monochromatic composite restoration.

Sample preparation-

The study was conducted in department of conservative dentistry and endodontics in maharishi Markandeshwar university after obtaining by the institutional review board. 60 premolars extracted for orthodontic purposes were taken for the study. Samples are then divided into two groups namely, Group A (Biodentine group) and

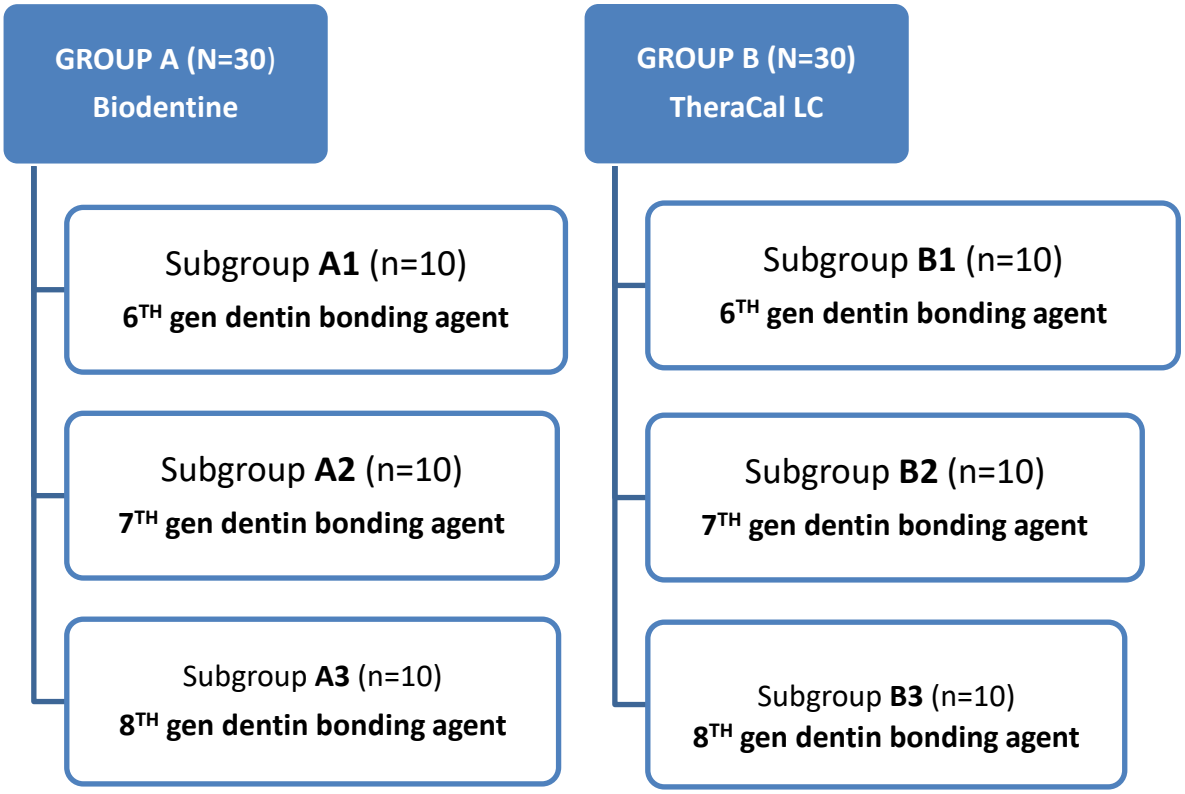
Group B (Theracal Lc) respectively. Each group is then further subdivided into subgroup A1 and B1 (6th gen dentin bonding agent), subgroup A2 and B2 (7th gen dentin bonding agent) and subgroup A3 and B3 (8th gen dentin bonding agent).

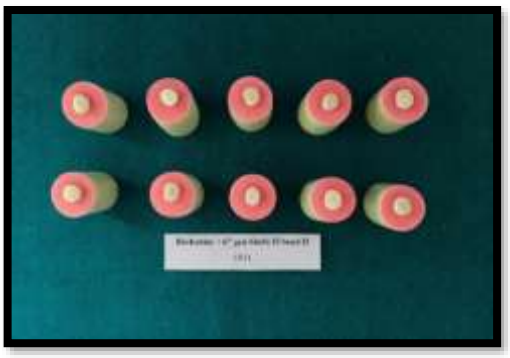
INCLUSION CRITERIA

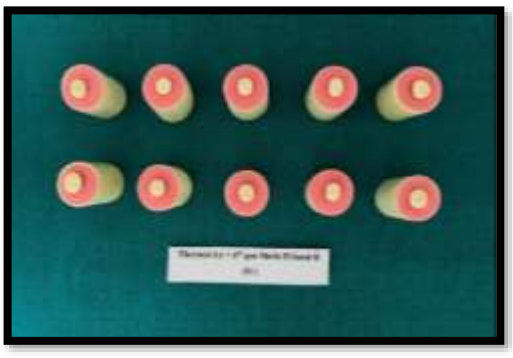
1. Premolars extracted for orthodontic purposes.
2. Tooth without caries, cracks, restorations and fracture defects.

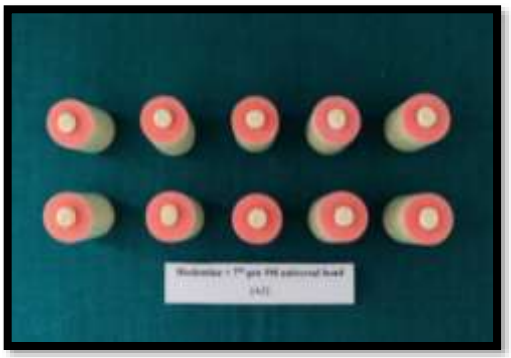
MATERIALS USED IN THIS STUDY - Biodentine (Septodont), Theracal LC (Bisco), Fl- bond II two step, self -etch adhesive system (Shofu), Single Bond Universal (SB) 3M ESPE, G-Premio Bond (GC), Omnichroma (Tokuyama).

Materials and methods-









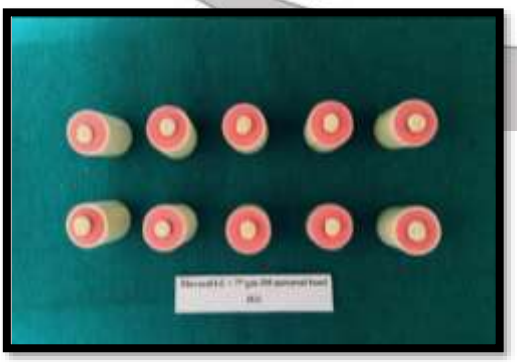


Fig 2. Restoration with monochromatic composite (Omnichroma)

Fig 3. Universal Testing Machine

METHODOLGY-

1 Tooth Preparation

- Root section of each extracted tooth placed in acrylic mold with occlusal surfaces parallel to the base.
- Cold cure acrylic resin (DPI-RR Cold CURE) poured – crown portion exposed.
- Mid-coronal dentin & occlusal surfaces flattened.

2. Base Material Placement (N=60)

Group A (n=30): Biodentine.

Group B (n=30): TheraCal LC.

- Materials manipulated as per manufacturer instructions

5. Shear Bond Strength Testing

• Mounted in Universal Testing Machine (fig3)
• Dentin surface parallel to load direction
• Knife-edge (1 mm) at interface
• Load applied at 0.5 mm/min
• Failure recorded

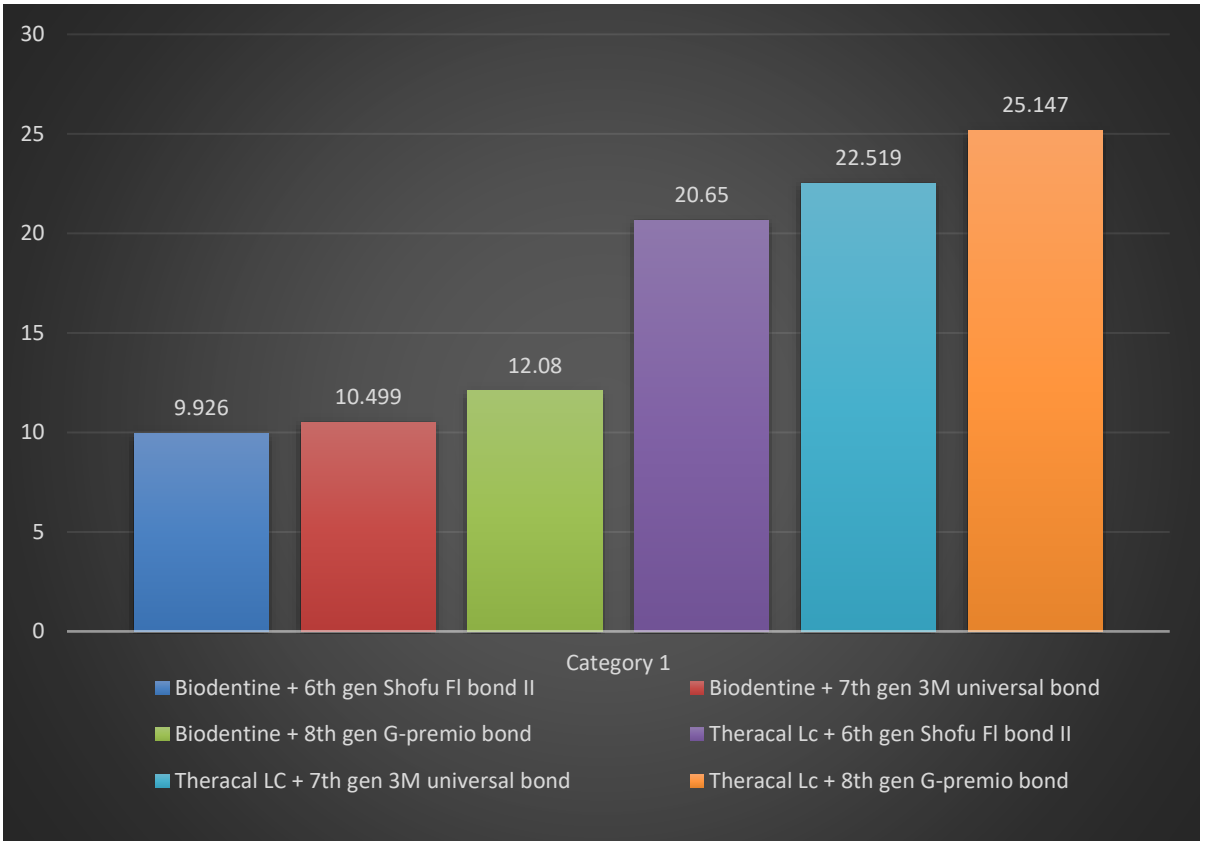
STATISTICAL ANALYSIS-Data were analyzed using IBM SPSS version 20 software (IBM SPSS, IBM Corp., Armonk, NY, USA). Descriptive statistics and one-way analysis of variance (ANOVA) with Tukey's post hoc tests were done to analyze the shear bond strength. Simple bar and percentage proportional bar diagrams were used for data presentation.

RESULTS:

Table 1: Comparison of shear bond strength among the study groups

Groups	Mean	Std.dev	Fvalue	Pvalue
Biodentine + 6th gen Shofu Fl bond II	9.926	1.2419	178.797	0.000*
Biodentine + 7th gen 3M universal bond	10.499	1.564		
Biodentine + 8th gen G-Premio bond	12.08	1.460		
Theracal Lc + 6th gen Shofu Fl bond II	20.65	1.957		
Theracal LC + 7th gen 3M universal bond	22.519	1.8098		
Theracal Lc + 8th gen G-Premio bond	25.147	1.404		

One-way anova p<0.05* significant



Graph 1: Comparison of shear bond strength among the study groups

Presents the comparison of shear bond strength between the study groups. There was a statistically significant difference between the study groups. It was noted that the mean shear bond strength was highest in the

Theracal Lc + 8th gen G-Premio bond (25.147±1.4) followed by Theracal LC + 7th gen 3M universal bond group (22.519±1.80), the Theracal Lc + 6th gen Shofu Fl bond II (20.6±1.957), Biodentine + 8th gen G-Premio bond (12.08±1.46), Biodentine + 7th gen 3M universal bond (10.499±1.564) and least shear bond strength was found in the Biodentine + 6th gen Shofu Fl bond II (9.926 ±1.24).

Table 2: Multiple comparisons using posthoc tukey analysis

Groups		Mean Difference	Sig.
Biodentine + 6th gen Shofu Fl bond II	Biodentine + 7th gen 3M universal bond	0.573	0.965(NS)
	Biodentine + 8th gen G-Premio bond	-1.581	0.245(NS)
	Theracal Lc + 6th gen Shofu Fl bond II	-10.151	0.000*
	Theracal LC + 7th gen 3M universal bond	-12.02	0.000*
	Theracal Lc + 8th gen G-Premio bond	-14.64	0.000*
Biodentine + 7th gen 3M universal bond	Biodentine + 8th gen G-Premio bond	-2.154	0.042*
	Theracal Lc + 6th gen Shofu Fl bond II	-10.724	0.000*
	Theracal LC + 7th gen 3M universal bond	-12.59	0.000*
	Theracal Lc + 8th gen G-Premio bond	-15.22	0.000*
Biodentine + 8th gen G-Premio bond	Theracal Lc + 6th gen Shofu Fl bond II	-8.57	0.000*
	Theracal LC + 7th gen 3M universal bond	-10.439	0.000*
	Theracal Lc + 8th gen G-Premio bond	-13.067	0.000*
Theracal Lc + 6th gen Shofu Fl bond II	Theracal LC + 7th gen 3M universal bond	--1.869	0.108(NS)
	Theracal Lc + 8th gen G-Premio bond	-4.497	0.000*
Theracal LC + 7th gen 3M universal bond	Theracal Lc + 8th gen G-Premio bond	-2.62	0.007*

Multiple comparisons using post hoc tukey test was done to check the shear bond strength among the study group.

Statistically significant difference in the shear bond strength was seen between Biodentine + 6th gen Shofu Fl bond II with Theracal Lc + 6th gen Shofu Fl bond II, Theracal LC + 7th gen 3M universal bond, Theracal Lc + 8th gen G-Premio bond.

Statistically significant difference in the shear bond strength was seen between Biodentine + 7th gen 3M universal bond with Biodentine + 8th gen G-Premio bond, Theracal Lc + 6th gen Shofu Fl bond II, Theracal LC + 7th gen 3M universal bond, Theracal Lc + 8th gen G-Premio bond.

Statistically significant difference in the shear bond strength was seen between Biodentine + 8th gen G-Premio bond with Theracal Lc + 6th gen Shofu Fl bond II, Theracal LC + 7th gen 3M universal bond, Theracal Lc + 8th gen G-Premio bond

Statistically significant difference in the shear bond strength was seen between Theracal Lc + 6th with Theracal Lc + 8th gen G-Premio bond

Statistically significant difference in the shear bond strength was seen between Theracal LC + 7th gen 3M universal bond with Theracal Lc + 8th gen G-Premio bond.

DISCUSSION-

Biodentine, a prominent new calcium silicate material, is marketed as a bioactive dentine substitute. Primarily composed of tricalcium silicate and zirconium oxide, with the addition of calcium carbonate and other minor constituents. It effectively induces odontoblastic differentiation from pulp progenitor cells, leading to the

formation of a mineralized matrix resembling natural dentin.[2]
TheraCal LC serves as an effective barrier and protector of the dental pulp by releasing calcium ions that stimulate odontoblast and fibroblast activity, promoting the formation of mineralized tissue. It forms a scaffold on affected dentin, encourages reparative dentin production, and establishes a chemical bond with dentin, thereby providing biological adhesion and shielding the pulp.[5]
In contemporary clinical practice, self-etch adhesives are widely employed. These systems utilize acidic functional monomers that simultaneously demineralize and prime the dentin.
Both adhesive systems bond to dentin by partially demineralizing it, while preserving residual hydroxyapatite around the collagen fibrils. This retained hydroxyapatite enables functional monomers, such as 10-methacryloyloxydecyl dihydrogen phosphate (10-MDP), to chemically bond with calcium ions.[6] Shofu FL-Bond II is a sixth-generation, (two-step self-etch adhesive system) that involves the use of a self-etching primer followed by a bonding resin. The formulation is free of HEMA and acetone, which helps to minimize postoperative sensitivity and also reduces the risk of hydrolytic breakdown at the adhesive interface.[7]
In contrast, 3M Universal Bond is a seventh-generation, (single-step self-etch adhesive) system was designed to simplify the bonding procedure while maintaining its compatibility with multiple substrates. It contains functional monomers such as 10-MDP, which facilitate chemical interaction with both dental hard tissues and restorative materials, thereby enhancing adhesion and interfacial stability.[7]
G-Premio Bond (GC, Tokyo, Japan) is classified as an eighth-generation, (single-step universal adhesive) that can be applied using self-etch, selective-etch, or total-etch techniques. It contains several functional monomers, including 10-MDP, 4-META, and MDTP, which allows chemical interaction with both tooth structure and restorative materials. In particular, the presence of 10-MDP promotes the formation of stable calcium salts with residual hydroxyapatite, thereby enhancing interfacial stability and supporting long-term bond durability.
In this study, Universal Testing Machine with the knife-edge positioned right at the composite-tooth junction were used for evaluation. Samples were mounted horizontally, ensuring that the blade was perfectly perpendicular to the composite-dentin interface. Load was applied until failure occurred, recording the peak shear force needed to debond each sample. Bond strength, expressed in MPa, was calculated by dividing the maximum load (in Newtons) by the cross-sectional area (in mm^2) of the composite cylinder. This shear bond test applies force parallel to the tooth surface, mimicking real-world clinical stresses more closely than other methods. Also, its straightforward setup delivers reliable, easy-to-interpret results—ideal for practical comparisons, marketing and material ranking.[8]
Hence, this in-vitro study, compared how well three different generations of bonding agents adhere to Biodentine and TheraCal LC when used under a monochromatic composite restoration. **Shear bond strength** is commonly used to evaluate adhesive performance; however, it does not represent the true stress at which failure occurs. Crack initiation may occur at stress levels higher than the nominal bond strength values, which reflects only an average stress distribution at the bonded interface.

Comparing the shear bond strength of Biodentine with 6th, 7th, 8th generation bonding agents.

Biodentine + 8th gen	>	Biodentine + 7th	>	Biodentine + 6th
12.08	>	10.926	>	9.499

Comparing the shear bond strength of Theracal LC with 6th, 7th, 8th generation bonding agents.

Theracal LC + 8th gen	>	Theracal LC + 7th	>	Theracal LC+ 6th
25.147	>	22.519	>	20.65

The present study results revealed that shear bond strength of Biodentine, showed a gradual increase from 6th to 8th generation adhesives. The difference between 6th vs 7th, 7th vs 8th & 6th vs 8th generation was not statistically significant ($p > 0.05$). The 8th generation G-premio bond provided the highest bond strength to biodentine suggesting that newer adhesive system may enhance bonding performance. The results were similar to a study done by Reddy CLC et al. (2025) and Lahiri et al. (2023).[9,10]
contrast results revealed that shear bond strength of Thercal LC also showed a gradual increase from 6th to 8th generation adhesives. A statistically significant difference between Theracal LC bound with the 6th and 8th generation adhesives ($p = 0.000$*) and between the 7th and 8th generation adhesives ($p = 0.007$*) was found by

post-hoc Tukey analysis. The 6th and 7th generation adhesive groups did not, however, show statistically significant (p = 0.108). In general, Theracal LC showed enhanced bond strength with self-etch adhesives of different generations, especially the 8th generation system.
Possible reasons for enhanced bond strength of Theracal Lc among different adhesives:

1. Resin modified composition of Theracal Lc
2. Improved chemical interaction with functional monomers
3. Superior wettability and penetration.

Fathi UA et al. (2023)[11] compared the shear-bond strength of TheraCal LC, Dycal and Biodentine liners to resin composite and reported that Theracal LC exhibited significantly higher bond strength compared to biodentine and Dycal.

When intergroup comparison is done-the study shows the following results:
A statistically significant difference in shear bond strength was found across the research groups based on intergroup comparison (ANOVA, F = 25.016, p < 0.001), suggesting that bond strength was highly impacted by both bonding generation and liner type.
Regardless of the bonding chemical utilized, TheraCal LC groups often showed significantly higher shear bond strength values than Biodentine groups. When Biodentine was utilized as the liner, no statistically significant differences between the 6th, 7th, and 8th generation bonding agents were found within the Biodentine groups (p > 0.05), indicating similar bonding effectiveness throughout adhesive generations.
Hashem et al. (2014)[12] reported that biodentine should be allowed to mature for two weeks before shear bond strength testing to resist composite polymerization stresses. In the present study, testing was performed after 24 hours to stimulate clinical conditions.
Chauhan u et al. (2020)[13] observed adhesive progression between newer generation dentin bonding agents, indicating 8th> 7th> 6th generation bonding agent regardless of substrate. The observed superiority of G-Premio bond with Theracal Lc (25.147 ± 1.404 Mpa) over 3M single bond universal (22.519 ± 1.80 Mpa, p= 0.007) aligns with silane enhanced formulation that optimizes chemical bonding to both resin monomers and calcium silicate phases simultaneously.
Thus, the highest shear bond strength values were obtained with Theracal LC
The limitation of this study was that-

- The study was conducted in vitro, so the oral environment was not fully duplicated.
- The research did not evaluate long-term durability; it only evaluated microleakage and short-term bond strength.
- The grading system used to evaluate microleakage may have included some observer bias.
- The study did not assess other clinically significant variables such as biocompatibility, postoperative sensitivity, or long-term clinical success.

Conclusion

TheraCal LC showed significantly higher shear bond strength than Biodentine with all bonding agents. The 8th generation adhesive demonstrated the highest bond strength, followed by the 7th and 6th generations. Biodentine showed lower and comparable bond strength across all adhesive systems, whereas TheraCal LC exhibited improved bonding with newer adhesives.

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